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# Design Science Research for Personal Knowledge Management System Development - Revisited

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## Abstract

The article presents Personal Knowledge Management (PKM) as an overdue individualized as well as a collaborative approach for knowledge workers. Designing a PKM-supporting system, however, resembles a so-called "wicked" problem (ill-defined; incomplete, contradictory, changing requirements, complex interdependencies) where the information needed to understand the challenges depends on upon one's idea for solving them. Accordingly, three main areas are attended to.

Firstly, in dealing with a range of growing complexities, the notion of Popper's Worlds is applied as three distinct spheres of reality and further expanded into six digital ecosystems (technologies, extelligence, society, knowledge worker, institutions, and ideosphere) that not only form the basis for the PKM System Concept named 'Knowcations' but also form a closely related Personal Knowledge Management for Development (PKM4D) framework detailed in a separate dedicated paper. Reflecting back on a United Nations scenario of knowledge mass production (KMP) over time, the complexities closely related to the digital ecosystems and the inherent risks of today's accelerating attention-consuming over-abundance of redundant information are scrutinized, concluding in a chain of meta-arguments favoring the idea of the PKM concept and system put forward.

Secondly, in light of the digital ecosystems and complexities introduced, the findings of a prior article are further refined in order to assess the PKM concept and system as a potential General-Purpose-Technology.

Thirdly, the development process and resulting prototype are verified against accepted general design science research (DSR) guidelines. DSR aims at creating innovative IT artifacts (that extend human and social capabilities and meet desired outcomes) and at validating design processes (as evidence of their relevance, utility, rigor, resonance, and publishability). Together with the incorporated references to around thirty prior publications covering technical and methodological details, a kind of 'Long Discussion Case' emerges aiming to potentially assist IT researchers and entrepreneurs engaged in similar projects.



**Keywords**: Personal Knowledge Management (PKM), Design Science Research (DSR), Informing Science (IS), Popper's Three Worlds, Knowledge Worker, Organizational Knowledge Management (OKM), Human Capital, Capacity Development, Lifelong learning, Digital Ecosystems, Complexity, Memes, Memex, Knowcations

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# PKM as an Individualized Tool for Knowledge Workers

Initially confined to the author's own Knowledge Management (KM) requirements, an idea formed for a personalized KM system which has been subsequently adapted and continuously expanded for the personal career support as a management consultant, scholar, professor, and academic manager. The experiences gained with the many stakeholders in the professional and academic world, as well as in the context of developed and developing countries, have reinforced the conviction that Personal Knowledge Management support is becoming ever more vital, a view shared by many other writers as discussed in prior papers (Schmitt, 2013f, 2014c) and as highlighted by some of the most prominent of these contributions:

- Seven decades ago, Vannevar Bush (1945) imagined the 'Memex'. As an inspiring idea never realized - lately celebrating its 70th anniversary - the 'Memex' represents the as-close-as-it-gets ancestor of the PKM concept and system proposed.
- Although progress only recently triggered the change from information scarcity to a never before experienced ever-increasing information abundance, the need for managing the scarce personal attention of those receiving it has been stressed by Simon (1971) already over four decades ago.
- In advancing his groundbreaking SECI-Model, Nonaka (Nonaka & Takeuchi, 1995; Nonaka, Toyama, & Konno, 2000) introduced the concept of 'ba' as a shared context or place (physical or virtual) and emphasized the importance of personal knowledge-related proficiencies, individual knowledge assets, personal autonomy, trust and commitment.
- For Wiig (2011), the PKM objective is the desire to make citizens highly knowledgeable to function competently and effectively in their daily lives, as part of the workforce and, as public citizens.
- For Levy (2011), the sustainable growth of autonomous capacities in PKM will be one of the most important future functions of teaching and higher education. He also envisages Knowledge Management experiencing a decentralizing revolution that gives more power and autonomy to individuals and self-organized groups. His scenario is based on decentralized autonomous PKM capacities, networked in continuous feedback loops to enable creative user conversations. Hence, PKM Systems (PKMS) are expected to facilitate the emergence of distributed processes of collective intelligence, which in turn feed them.

However, only current advances in development, hosting, and database platforms have provided a viable opportunity for further advancing the PKM prototype system and converting it into an application serving a wider audience across technological environments.

In parallel to this ongoing software development, further studies of the relevant fields and the publishing of a series of posters, papers, and articles (Schmitt, 2012-2016) have taken place, adding to the insight that the potential benefits justify a far more holistic approach by also encompassing the educational and developmental needs of the emerging knowledge societies. Since these published resources are accessible by using the cited URL and DOI links, this article shifts from a scenario of how Personal KM devices support individuals' academic and professional growth towards an account of how this novel concept and system has been devised. The aim of this article is thus to retrospectively focus on the design thinking approach taken in the light of recognized design science research frameworks in Information Systems. The outcome adds a novel perspective by sharing the design thinking methodologies adopted to structure the underlying rational and creative processes of the PKM system development project. Part of the article incorporates an unpublished presentation contributing to the Design Thinking Workshop at the 2015 UCT ETILAB conference (Schmitt, 2015j). As indicated in the title, the initial conference paper (Schmitt, 2016e) has been revised and updated, and the sections concerning ecosystems and knowledge mass production have been added.

# PKM as a Collaborative Tool for Knowledge Workers

On the one hand, the novel PKM approach benefits the personal, educational, and professional spheres of individual learning and working environments by deviating from the traditional Organizational KM (OKM) systems in four major ways:

- Its *Personal Focus* ensures one's digitalized knowledge is always at one's disposal and can easily be retrieved, expanded, shared, and re-used independent of changing one's social, educational, professional, or technological environment (Schmitt, 2012, 2014d, 2014f).
- Its *Bottom-up Focus* entails a departure from today's centralized, top-down, institutional KM developments. However, common knowledge-related methods, resources, and objectives provide strong arguments to exploit synergies between PKM and OKM systems for mutual benefit (Schmitt, 2014h, 2015b, 2015f, 2016d).
- Its *Meme Focus*, probably the most radical departure from the current document-centric KM systems, attends to the capturing, storing, and re-purposing of basic information structures (memes or ideas) and their relationships (to create knowledge assets and documents) rather than storing and referencing them the conventional way in their containers only (e.g., book, paper, report) (Schmitt, 2014j, 2014l, 2015e, 2015g, 2016a).
- Its *Creative Conversation Focus* is based on the shared aggregated meme trajectories between PKM system users and provides a multitude of enhanced options to engage in one's topics of interest. Also, collaboratively interlinking knowledge bases to collectively trace, harvest, and utilize accumulated knowledge subsets will overall reduce redundant content and improve productivity of information seekers and suppliers alike. Thus, the mission of a proposed 'World Heritage of Memes Repository (WHOMER)' is to guarantee continued access to the collective knowledge and ideas voluntarily shared among the PKMS user community as well as to overcome the redundancy, the perishability, and potential fallibility of current online knowledge, services, and providers (Schmitt, 2015c, 2015i).

On the other hand, considerable attention has been devoted towards aligning the PKM design elements with renowned concepts, methodologies, and heuristics in order to promote transparency and suitability, for example:

- Adopting Maslow's Extended Hierarchy of Needs, a *PKM for Development* (PKM4D) framework devised, differentiates the impact of the PKM concept according to twelve socially relevant criteria. While each of them positively impact on the individual (exciters & delighters), their absence and the lack of other potentially appropriate tools will have detrimental effects (inhibitors & demotivators). At an aggregated societal level, these criteria closely link to the various opportunity divides currently discussed (Schmitt, 2014k, 2015a, 2016h).
- Positioned in the historic context of emerging knowledge types and *human civilization*, the PKM concept has been portrayed as a novel technology able to promote individualization as well as collaboration providing the basis for the '*Next KM Generation*' as well as for a *General-Purpose Technology* (Schmitt, 2014b, 2015f, 2015h) or *Disruptive Innovation* (Schmitt, 2016g).
- Focusing on the *educational synergies* with the PKM concept (Schmitt, 2014m, 2015k, 2016b, 2016f; Schmitt & Butchart, 2014), dedicated presentations documented the methods adopted/adapted in form of papers with extensive visualizations (Schmitt, 2013c, 2013e, 2013g, 2014a, 2016c), posters (Schmitt, 2013b, 2013d, 2014n), demonstrations (Schmitt, 2014i), or e-Learning concepts.

- Utilizing the systems thinking techniques of the transdiscipline of *Informing Science* (IS), the PKMS design has been validated against Cohen's IS-Framework, Leavitt's Diamond Model, the IS-Meta Approach, and Gill's and Murphy's Three Dimensions of Design Task Complexity (Schmitt, 2015d).

# PKM as a Means to Deal with Growing Complexities

The latter IS-framework validation exercise also followed up on three mission-critical questions:

- How would a system based on the personal knowledge management concept be able to better serve the growing creative class of knowledge workers and the innovation agenda of knowledge economies compared to current solutions?
- How can personal devices help in mastering the ever-increasing information abundance, the changing spheres of work, the widening digital and innovation divides, and the needs for self-development and e-collaboration?
- Given a widely quoted early KM definition as the process of capturing, distributing, and effectively using knowledge (Davenport 1994), how can such basic activities be redesigned to make a difference?

The answer aligned Gill's and Murphy's (2011) three dimensions of Design Task Complexity

- *Objective Complexity* referring to the number and dynamics of elements and their interrelationships, measured by *Ruggedness*,
- *Unfamiliarity* referring to the lack of structure, guidance, and/or task-specific knowledge as well as to inadequate tools, measured by *Perceived Difficulty*,
- *Problem Space Complexity* referring to the constraints, uncertainty, and irreversibility associated with the information processing and their solutions, measured by *Path Entropy*,

to the needs addressed by the PKMS features offered. Instead of increasing all three complexities without intervention, employing PKMS devices is able "to scale down each one of the complexities discussed in order to subsequently create 'productive' spaces for efficient storage, improved learning, assisted authorship, and innovative knowledge utilization which are able to better absorb and share prospective knowledge advances". Some of the complexity-reducing features have also been exemplified and visualized in a PKMS Design Task Complexity Cube (Schmitt, 2015d).

A subsequent article (Schmitt, 2015h) takes these findings further and assesses the prospect of whether the PKMS concept and prototype system has got what it takes to grow into a transformative General-Purpose-Technology. Clustered into ten categories (advancement, systemics, transparency, productivity, performance, universality, shared aims, traceability, dominance, and spawning), the summarized conclusions extend over all three complexities and their intersections. The categories and complexities will be further refined with the introduction of the digital ecosystems in this article.

With this article's retrospective focus on the design thinking approach taken, the three complexity dimensions play again a pivotal role and are further examined in light of Popper's Three Worlds (1972, 1978) and digital ecosystems. The article then introduces the notion of Theory Effectiveness and the significance of Design Science Research frameworks and guidelines for the discipline of Information Systems. The design thinking process leading to the PKMS concept and system is subsequently portrayed by fitting it to these guidelines and the 'three world' perspective.

## Popper's Worlds as Three Distinct Spheres of Reality

*Popper's Three Worlds* (1972, 1978) differentiate reality into three distinct spheres (Figure 1). *World:1* comprises the *concrete objects* and their relationships and effects in the real physical world. *World:2* refers to the results of the mental human *thought processes* in the form of subjective personal knowledge objects. *World:3* represents the *thought content* made explicit in the form of abstract objective knowledge objects which express the products of *world:2* mental processes. The arguments for PKM Solutions made previously in the context of technological progress (Schmitt, 2014b) are closely related to Popper's world view.

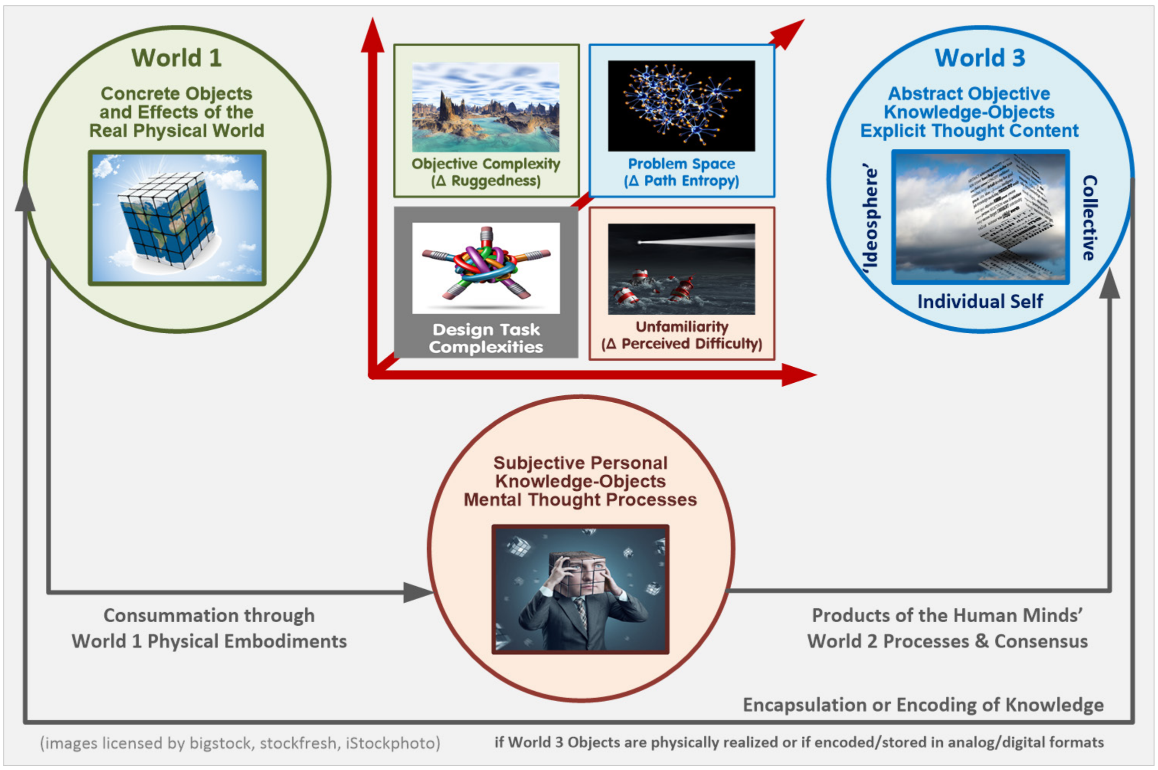


**Figure 1. Popper's Three Worlds and Design Task Complexities Encountered**

- *World:1*'s rising populations and higher innovation rates mean that not only the number of entities to deal with is growing, but that their potential relationships and effects are subjected to a combinatorial explosion and a mounting objective complexity. The accelerating change also renders physical and social technologies and their documented representations more rapidly obsolete than ever before. Accordingly, a PKMS's knowledge base structure has to be able to accommodate all entities and relationships deemed relevant and to keep track of any dynamic changes. The main emphasis is on *Objective Complexity.*
- Reflecting on which of one's acquired know-who/how/why/where/when/with/abouts might become outdated and directing one's attention to the relevant organizational, commercial, social, and legal innovations, thus, becomes a pre-condition for keeping one's personal *world:2* knowledge capitals a-jour, for familiarizing oneself with the potential game changers, and/or for adding one's conclusions and ideas to the *world:3* extelligence[1]. To support the underlying thought processes, a PKMS needs to conserve and monitor one's

[1] Stewart and Cohen (1999) introduced the term 'Extelligence' for externally stored information; it forms the external counterpart to the intelligence of the human brain/mind and deals in information whereas intelligence deals in understanding; together they are driving each other in a complicit process of accelerating interactive co-evolution.

(un)knowns (Extended Ignorance Matrix (Schmitt, 2013e, 2015d)) and guide the knowledge acquisition, creation, and exploitation activities (PKM Value Chain (Schmitt, 2013c, 2015d)). The main concern is the *Complexity* related to *Unfamiliarity. World:2* represents the mind of the *knowledge worker* following Gurteen's (2006) wider definition[2].

- *World:3* resembles a representation of the entire accumulated explicit human know-how and experience. For Popper (1972), only formulated thoughts can be shared and criticized. As abstract objective *world:3* objects, these thoughts stand on their own, are independent of their creators, and should be judged on their own merit. However, to elicit impact on *world:1* physical objects and/or other *world:2* minds, the abstract *world:3* objects have to be resourcefully combined (path entropy) and physically embodied or realized in concrete *world:1* objects. They need to be incorporated into either *inanimate vectors* (such as buildings, machines, factories, products, software, storage devices, books, great art, or major myths) or *living hosts* (such as people, teams, corporations, or economies). PKMS functionalities, hence, have to support the underlying knowledge tracing, configuration, and creative authorship activities. The main focus shifts to deal with *Problem Space Complexity. World:3* represents - what has been termed in prior publications – the '*Ideosphere*'[3]

All three worlds are highly interactive: "*World:2* acts as an intermediary between *World:3* and *World:1*. But it is the grasp of the *World:3* object which gives *World:2* the power to change *World:1*" (Popper, 1978). The agents interacting between the worlds, as adopted and adapted by the PKMS concept, are *memes*, originally described as units of cultural transmission or imitation (Dawkins, 1976) that evolve over time through a Darwinian process of variation, selection, and transmission. As explicit representations, memes add to the *world:3* memory of human thinking.

But, in order to survive, memes have to be able to endure in a medium they occupy and the medium itself has to persevere. They can either be encoded in durable *world:1* vectors spreading almost unchanged for millennia, or they succeed in competing for a host's *world:2* limited attention span to be memorized (internalization*) until they are forgotten, codified (externalization*) in further *world:1* objects or spread by the spoken word to other hosts' *world:2* brains (socialization*) with the potential to mutate into new variants or form symbiotic relationships (combination*) with other memes (memeplexes) to mutually support each other's fitness and to replicate together (*-markings refer to comparable SECI Model stages (Nonaka & Takeuchi, 1995; Schmitt, 2014m, 2016b)). To incorporate this memetic thinking into the PKM approach, Popper's Three Worlds have been further differentiated into six Digital Ecosystems,

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[2] Gurteen (2006) places - rather than the socio-economic criteria of an individual's type of work as in Florida's (2012) Creative Class - the virtue of responsibility at the center of his reflections: "Knowledge workers are those people who have taken responsibility for their work lives. They continually strive to understand the world about them and modify their work practices and behaviors to better meet their personal and organizational objectives. No one tells them what to do. They do not take 'no' for an answer. They are self-motivated". To Gurteen's mind, they "cannot be coerced, bribed, manipulated or rewarded and no amount of money or fancy technology will 'incentivize' them to do a better job. Knowledge workers see the benefits of working differently for themselves. They are not 'wage slaves' - they take responsibility for their work and drive improvement".

[3] Memetics studies ideas and concepts viewed as 'living' organisms, capable of reproduction and evolution in an 'Ideosphere' (Sandberg, 2000), an "invisible but intelligible, metaphysical sphere of ideas and ideation" where we engage in the creation of our world. "This means that the substance of the world is idea, which forms, reforms, and transforms itself via the conversations of humankind, synergetically organizing itself as an evolutionary, multidimensional network [with technology just an artefact of idea]. The problem, as Kimura (2005) notes, is that the majority of 'humanity remains the consumer of ideas without being the producer". Hence, what is called for is an ideospheric transformation set off by a synergetic phenomenon that emerges "when individuals in sufficient numbers become authentic, independent thinkers, that is, originators of ideas, producers of dialogues, and contributors to the network of conversations that comprises the world".

# PKM – From Popper's Worlds to Digital Ecosystems

Briscoe (2010) introduces his conceptual Digital Ecosystem (DE) framework as a means to support the cross pollination of ideas, concepts, and understanding between different classes of ecosystems. To fit the PKM context, six distinct ecosystems have been demarcated (technology, extelligence, society, knowledge worker, institutions, and ideosphere) and defined based on a modified set of key properties, behaviors, and structures (Figure 2). The resulting six clusters represent the relevant landscape of knowledge creation and learning and are meant to transparently map how the PKMS's structures and processes interact with the meta-concept of Popper's worlds.

Figure 2 depicts the ecosystem associations between the *world:2* individual mind with itself (knowledge worker) and *world:2* collective minds (society and institutions) as well as with the *world:1* (extelligence and technology) and *world:3* objects (ideosphere).

Currently, each of the six ecosystems harbors its fair share of 'unsustainabilities' hampering the development and necessary transformation of people, institutions, and societies to be further attended to. Each ecosystem also shapes the Personal Knowledge Management for Development (PKM4D) framework; initially designed to provide individuals with twelve step-by-step criteria for PKM-related capacity development (Schmitt, 2014k), the PKM4D framework has been expanded and paired with the six ecosystems (to be detailed below) allowing for the differentiated assessment of KM-related innovations and interventions and their impact (Schmitt, 2016h).

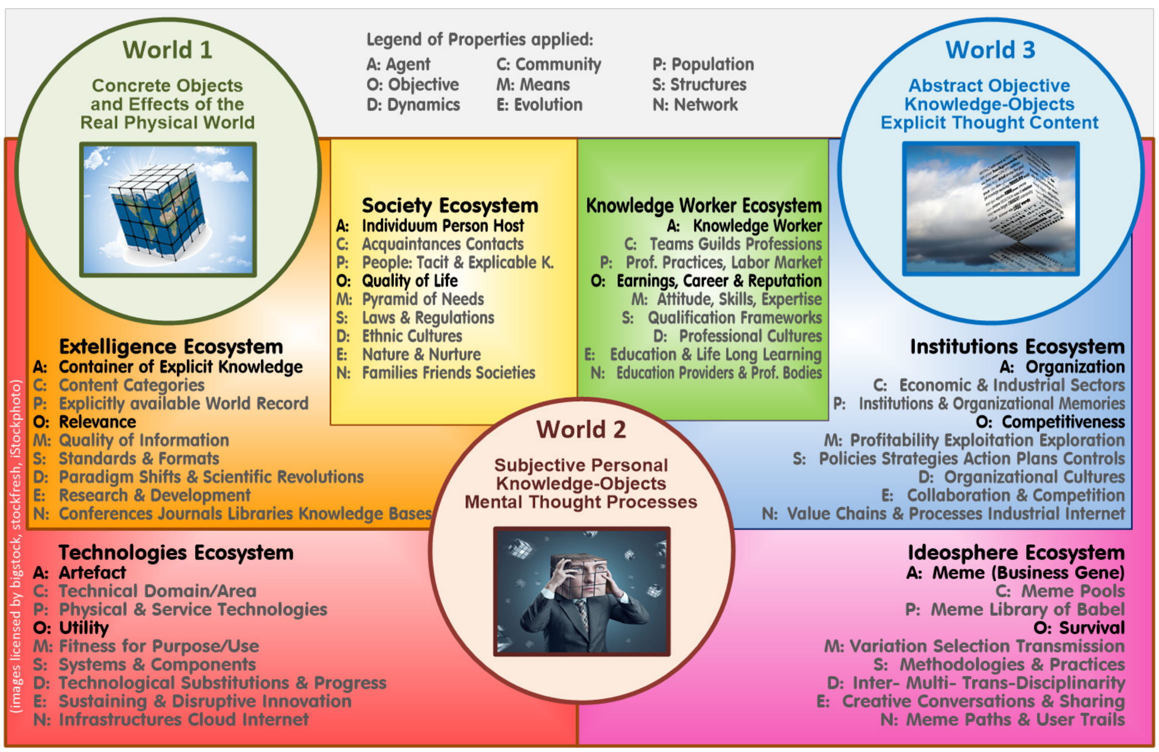


**Figure 2. Profiles of Six Ecosystems interacting with Popper's Three Worlds**

## The Technologies Ecosystem

The technologies ecosystem represents the interactions between the *world:2* minds with the *world:1* artefacts characterized by their technical domain or area. Its evolutionary progress is based on a co-evolution of physical and social (including service) technologies directed by business plans (Beinhocker, 2006). Novel technological systems and their components are selected based on their utility and fitness resulting in sustaining (incremental improvements), disruptive innovations (substitutions), or failing product launches. Knowledge (explicit representations in words, numbers, symbols excluded) is foremost encapsulated in an artefact's design and functionality, but can be extracted, for example, by measuring, testing, or reengineering.

Hughes (2011) makes the point that progress has not only thrived on improved memory and communication technologies, but that the recent advances in ICTs (e.g., infrastructures, internet, cloud) and their widespread affordability are also accompanied by an insatiable urge of *world:2* minds to use these technologies for the purposes intended. One further development under way – set to become the fourth industrial revolution – is termed the 'Industrial Internet' (Evans & Annunziata, 2012) and facilitates machine learning, machine-to-machine communication, big data analytics, and the Internet of Things by incorporating networked sensors, software, and explicit knowledge into goods and machines resulting in the self-organizational capability of complex value chains. But, although "we have many powerful applications for locating vast amounts of digital information, we [still] lack effective tools for selecting, structuring, personalizing, and making sense of the digital resources available to us" (Kahle, 2009).

## The Extelligence Ecosystem

The extelligence ecosystem embodies the interactions of *world:2* minds with the content of *world:1* explicit knowledge containers (e.g., books or digital files) as characterized by subject categories within the documented world record available. Extelligence is selected on its relevance (e.g., learning, record keeping, or entertainment value) and the quality, standards, and/or formats of its data, information, or knowledge components. The evolution of its content has been shaped by particular physical and social innovations (e.g., language, writing, printing, institutional record keeping, digitization, ICT, cloud computing, and industrial internet), while its meaning has undergone significant revisions due to paradigm shifts, scientific and industrial revolutions (Kuhn, 1970; Taylor, 1947). Scholarly extelligence is based on a cumulative process involving research and development, curation, conferences, journals, libraries, and knowledge bases. Its "success depends on wide and rapid dissemination of new knowledge so that findings can be discarded if they are unreliable or built on if they are confirmed" (Borgman, 2007). But, as pointed out earlier, the familiar problem of information scarcity (few sources/channels, high associated costs) has been recently replaced by a never before experienced ever-increasing attention-consuming information abundance to be further inflated by the forthcoming 'Industrial Internet'

## The Society Ecosystem

The society ecosystem is the habitat of the individual person's *world:2 mind* interacting with other *world:2* minds (one's acquaintances and contacts) through their *world:1* bodies and senses resulting in the *world:2* personal subjective tacit knowledge which might or might not be explicable by its host through *world:1* concrete explicit knowledge objects via their *world:3* abstract objective process stage. Primarily, the mind's reasoning is motivated by a quest for a better quality of life exemplified by, for example, Maslow's extended Pyramid of Needs (Koltko-Rivera, 2006), restrained, however, by the scarcity of resources as well as by ethical considerations, laws, and regulations imposed to care for the *world:2* diverse communities and/or the *world:1* environment.

## The Knowledge Worker Ecosystem

The knowledge worker ecosystem is an extension of the general social ecosystem providing a space for *world:2* knowledge workers as constituents of *world:2* collective mind sets (e.g., teams, guilds, or professions) engaging in leisurely and professional practices or labor markets. Motivated by earnings, reputations, or career prospects, developing one's attitudes, skills, and expertise is key for advancing into *world:1* desired work positions regulated by qualification frameworks and shaped by professional cultures. Needs for constant transformations caused by the accelerating dynamics of organizational, commercial, social and legal innovations demand a quality education followed by lifelong learning obtainable from affordable and effectual education providers or professional bodies. However, unlike manual workers, experienced knowledge workers are able to choose where, how, and for whom they will put their increasingly distinctive and mobile knowledge and expertise to work. Since knowledge and skills are portable and mobile, professionals ought to be able to keep, maintain, and advance their personal knowledge on their own personal devices and to share it with acquaintances, if desired.

## The Institutions Ecosystem

The institutions ecosystem is an extension of the knowledge worker ecosystem providing a space for *world:2* professionals and their stakeholders to form institutions (defined as "snapshots of a subset of the ideational field that persevere while the network itself continues to fluctuate" (Kanengisser, 2014) with organizational intelligence and memories operating in particular cultural, public, and economic sectors. The driving force is relevance and competitiveness based on capabilities to successfully exploit and further explore and advance one's institutional portfolio of interests leading to reputation and/or profitability. Policies, strategies, action plans, and controls guide these endeavors by either competition or collaboration networked via processes, value chains, or the industrial internet with the emergence of distinct organizational cultures. However, the overall performance and viability of enterprises and societies result from the organizational and departmental aggregation of innumerable small 'nano' actions by individuals (Wiig, 2011). A recent meta-study has just confirmed this order by observing the strongest association between creativity and innovation not at the team but at the individual level: Firms ought to "identify, nurture, and effectively deploy ambidextrous individual researchers and also consider them for participating in innovation teams" (Sarooghi, Libaers, & Burkemper, 2015; Schmitt, 2016d).

## The Ideosphere Ecosystem

The ideosphere ecosystem connects the *world:2* minds with their *world:3* abstract objective knowledge objects. In Memetics, these *world:3* objects, as pointed out, are viewed as 'living' organisms, capable of reproduction and evolution, and – in the PKM context – the 'Ideosphere' ecosystem is the habitat of memes or 'Business Genes' as re-labeled by Koch (2001) to better fit the commercial context. Able to self-replicate by utilizing the *world:2* mental storage, these (cognitive) information-structures influence their hosts' behavior to promote further replication (Bjarneskans, Grønnevik, & Sandberg, 1999). From a meme's-eye view, every *world:2* human mind is a machine for making more memes, a vehicle for propagation, an opportunity for replication, and a resource to compete for (Blackmore, 2000). But, memes exist only virtually and have no intentions of their own; they are merely information pieces in a feedback loop with their longevity being determined by their environment (Collis, 2003). The full diversity of memes accessible to a culture or individual is referred to as 'meme pool' (G. Grant, Sandberg, & McFadzean 1999) and each one forms – in the PKM ideosphere – an atomic building of 'memeplexes' or 'knowledge assets' (defined as non-physical claims to future value or benefits (Dalkir, 2005)).

# PKM – From Ecosystems to Refined Complexities

The refinement of Popper's Three Worlds into six digital ecosystems also allows for a further differentiation of the complexities alluded to (Table 1). The three interrelated dynamic complexities pointed out already (with their best-fit ecosystem counterparts) are the following: Rising ruggedness due to the rising number and dynamics of *world:1* objects and their interrelationships (Technology); Perceptions of mounting difficulties due to accelerating change to be encountered by *world:2* knowledge workers without adequate task-specific knowledge, guidance, and/or tools (Knowledge Worker); Accelerating path entropy characterized by intensifying constraints and escalating numbers of paths leading to increasingly uncertain outcomes (Ideosphere).

Accounting for the particular challenges of knowledge management, the three additional complexity dimensions pay attention to aspects of unsustainable developments[4] (Figure 7). They address issues currently not adequately addressed associated with an accelerating over-abundance of extelligence (Emergent Properties and Ignored Synergies), an escalating potential of social conflicts (Social Complexity and Opportunity Divides), and the ever more pressing need for sustainable solutions (Innovativeness and Absorptive Capacity).

While some of the related concerns are covered in this article, others will be addressed in follow-up papers discussing PKM in the context of affordances and fixations as well as sustaining and disruptive innovations. However, to demonstrate the suitability of this complexity framework, Figure 3 refines the findings of the prior article mentioned (Schmitt, 2015h) which assessed the PKM concept and system as a potential General-Purpose-Technology (GPT).

In re-clustering the terms and criteria proposed (Cantner & Vannuccini, 2012), the twelve categories (memory, approach, spawning & indexing, tracking & services, paradigms, commitment, capability, productivity, performance. ambitions, utility, and dominant design) have been supplemented by some of the respective PKM affordances or functionalities and aligned to the six complexities in order to strengthen evidence in terms of PKMS's GPT affinities.

**Table 1. Popper's Worlds aligned to the Six Digital Ecosystems and their Complexities**

| Popper's Worlds | Digital Ecosystem | Complexity | Measurement |
|---|---|---|---|
| Concrete Objects and Effects of the Real Physical World (*World:1*) | Technology | Objective Complexity | Ruggedness |
| | Extelligence | Emergent Properties | Ignored Synergies |
| Subjective Personal Knowledge-Objects Mental Thought Processes (*World:2*) | Society | Social Complexity | Opportunity Divides |
| | Knowledge Worker | Unfamiliarity | Perceived Difficulty |
| | Institutions | Innovativeness | Absorptive Capacity |
| Abstract Objective Knowledge-Objects Explicit Thought Content (*World:3*) | Ideosphere | Problem Space | Path Entropy |

[4] The notion of sustainable impact attracts increasing attention in Design Science Research (DSR). Gill and Hevner (2013), for example, propose complementing the research goal of usefulness with a fitness-utility model that "better captures the evolutionary nature of design improvements and the essential DSR nature of searching for a satisfactory design across a fitness landscape".

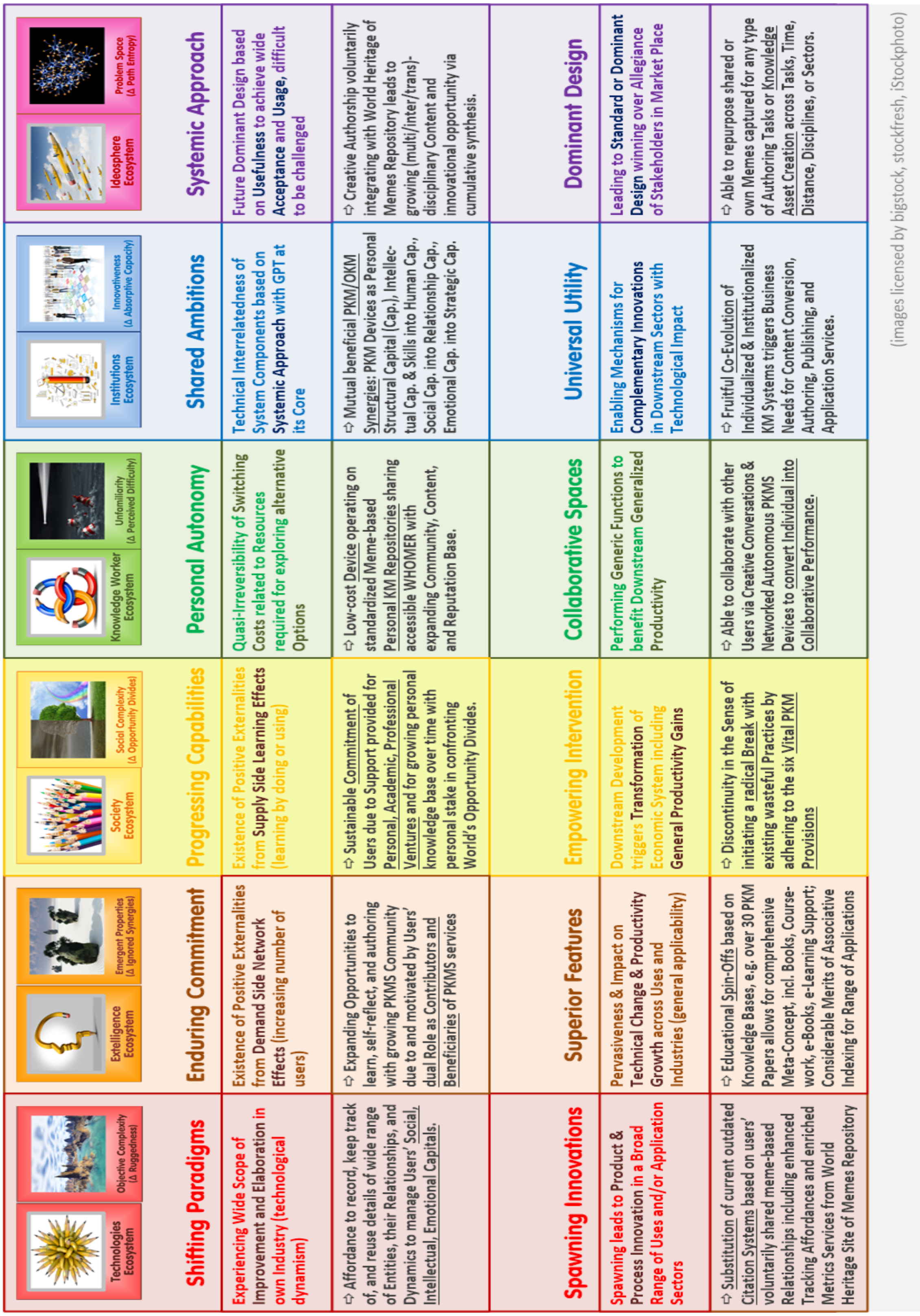


**Figure 3. General-Purpose-Technology Attributes versus PKM Complexities and Features**

# Digital Ecosystems versus Knowledge Mass Production

Emerging from the investigation of Popper's three worlds and their related ecosystems are six closely interrelated dynamic complexities. Their presence as well as related further looming predicaments are evident in an UN Report from a decade ago. 'Understanding Knowledge Societies' (United Nations, 2005) reflected on the future ICT supply needs by depicting three evolving factors of knowledge mass production (KMP) over time (Figure 4).

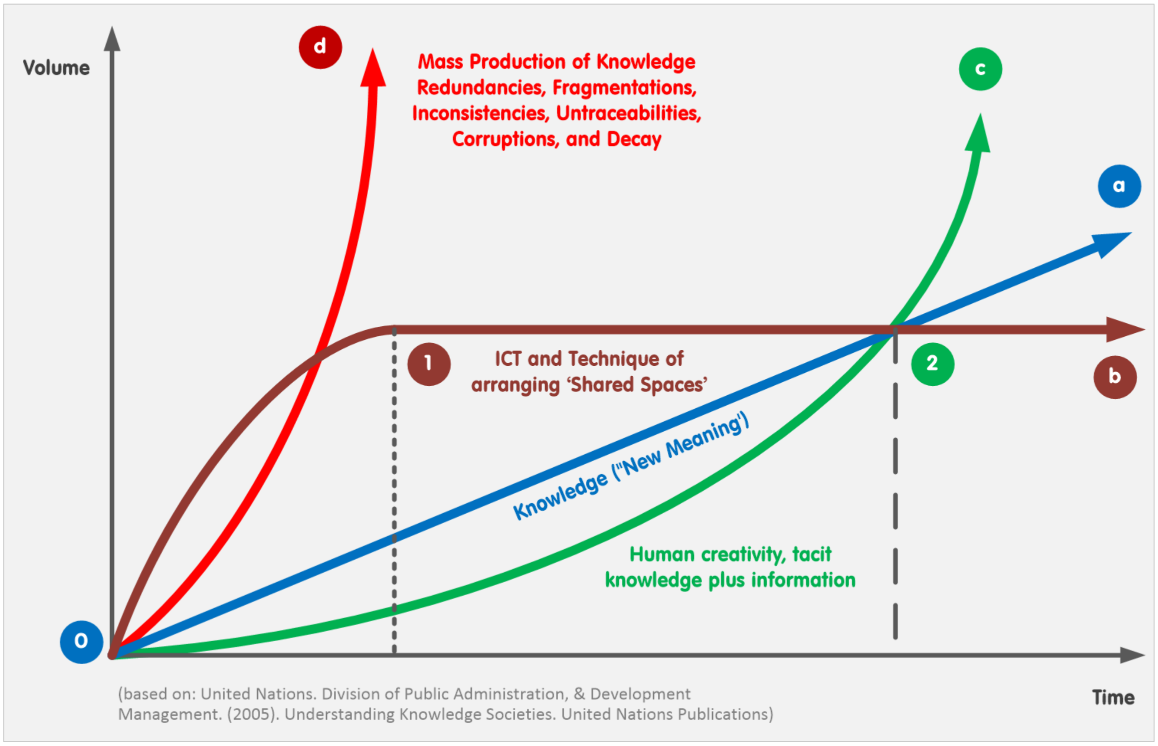


**Figure 4. Evolving Factors of Knowledge Mass Production**
(based on United Nations, 2005)

- Graph a (blue) indicates a continuous growth in 'new meaning' (or *world:3* accumulated explicit human know-how and experience *respectively: ideosphere ecosystem*) being created by the creative processing of knowledge and information already available resulting in the 'added value' of new uses and applications.
- Graph b (brown) signifies an accelerating *world:1* 'impact of modern ICT' infrastructures (*respectively, technology and extelligence ecosystems*) on KMP which is bound to slow down and eventually reaches its limits. Adding further speed and precision via ICT will start turning out diminishing benefits since sets of explicit knowledge products containing the minimum information for further processing will at that point become 'instantaneously' available, reaching a kind of ultimate accomplishment. Today, the still largely untapped potential (point 0, Figure 4) defines the current role of modern ICT as the KMP's engine of progress which will facilitate even more *world:1* organizational, commercial, social, and legal innovations for some time to come. Compared to the vast transformational institutional investments needed to "release the power of human creativity of all people everywhere", ICT also provides an option which is far less expensive to develop and apply.
- Graph c (green), growing slowly initially, "will start dominating this process pretty much in an uncontested way" based on the *world:2* human factor (*respectively, knowledge worker and affiliated society and institutions ecosystems*) representing the limitless development

> of people and information. When further ICT benefits will dry up (point 1), this 'human creativity, tacit knowledge plus information' factor will start driving KMP; the nature of institutional transformations will determine the steepness of its curve and the point in time when human capabilities will become the dominant KMP accelerator (point 2).

Unfortunately, the UN's KPM scenario is facing a considerable threat not even addressed by the report which has been added to the chart as an exponentially growing graph d (red). It originates as a spinoff from the other three factors as emerging properties in the form of the accumulating redundancies Simon (1971) referred to that are populating our digital repositories *representing the extelligence ecosystem*. Based on personal experience and anecdotal evidence, one can safely assume that the accelerating over-abundance of information reported (Hilbert, 2011; Short, Bohn, & Baru, 2011) contains rising stakes of redundancy, excess, and waste which unnecessarily divert the very attention our finite cognitive capabilities are able to master from dealing with more pertinent issues.

This sorry and unsustainable state arises at the *world:3/ideosphere* to *world:1/extelligence* interface where these redundancies originate following in the wake of the first concretization of an original abstract objective *world:3/ideosphere* knowledge object as its *world:1/extelligence* instantiation, triggered by, for example, duplications and citations of the original source (redundancies), partial (fragmentations) or erroneous (inconsistencies) replications or deletions, non-disclosure or subsequent erasure of sources (untraceabilities), unsuitable alterations of content (corruptions) or lacking curation and maintenance (decay).

Similar to focusing on 'Unlearning Unsustainabilities' in the context of education for sustainable development (McGregor, 2013) future digital libraries and KM system concepts are well advised to take up the challenge of 'Defusing Unsustainabilities' caused by redundant 'knowledge excess or waste' for strengthening the continued viability and sustainability of the UN's KMP scenario. Only effective and efficient accessibility to the *world:3* accumulated human record provides the source for the future and current limitless development of people and knowledge, which highly depends on pairing human creativity and tacit knowledge with the extelligence available.

A solution – in theory – is simple: Provide a novel *world:1:3* knowledge base or digital library where only the unique original *world:2* mental objects are represented in their explicit *world:3/ideosphere* format and enable direct access for the *world:2* minds. But, this is – in practice – exactly what the PKMS is supposed to do and why it links up with all the six ecosystems occupying the center stage between the three worlds (as shown in figure 7 later in this paper).

However, Popper's notion of the three Worlds has not only been instrumental in motivating this solution as one of the outcomes of the system development project, it also has guided the structuring of the underlying design science research processes to be elaborated further.

# PKM – From Conceptual Model to Prototype System

In "Towards an Ontology of Innovation Models", O'Raghallaigh, Sammon, and Murphy (2011b) bemoan that most – including even the latest – management concepts and models "emanating from the academic discourse fall well short of organizational reality" and that only few "are ever translated into software-based tools." In a prior paper (O'Raghallaigh et al., 2011a), the same authors therefore plead for designing a concept of *Theory Effectiveness* which characterizes a theory "that is incrementally and iteratively designed in order to be purposeful – both in terms of its utility (which is largely a matter of content) but also in its communication (which is largely a question of presentation) to an audience."

Thus, in addressing the problems of logic and objectivity in science, O'Raghallaigh et al. (2011a) introduce the 'big-T theory' labeling a *world:3/ideosphere* semi-linear abstract object derived from a scholar's nonlinear *world:2* vision. Various elements of this 'big-T theory' might then need to be embodied into subsets as 'small-T theories', the label assigned to *world:1* concrete objects such as research papers, conference presentations, or prototypes. While the 'big-T theory' is critical to representing aspects of a reality, the 'small-T theories' are critical to disseminating to an audience an understanding of that reality. The ensuing criticism of the social interactions may result in the 'big-T theory' being discarded, being re-conceptualized, or seeking further justification.

In following the modus of 'theory falsification' (Popper, 1959), the quality of the 'big-T theory' can only be determined indirectly via its 'small-T theories' embodiments, either from the reaction by peer reviewers or an audience or from their impact on *world:1* objects. Notwithstanding the struggles of closely aligning the vision with its 'big-T' and 'small-T' counterparts and of promoting theory generalization or contextualization, O'Raghallaigh et al. (2011a) point to the endemic failures of engaging in research relevant to the needs of stakeholders and to the endemic failures of adequately translating knowledge for the relevant audiences' fruitful consumption. Achieving theory effectiveness, thus, requires placing utility and communication at the core of all theory.

Peffers, Tuunanen, Rothenberger, and Chatterjee (2007) attribute these shortcomings to the still dominant traditional descriptive research paradigm of the social and natural sciences: "While design, the act of creating an explicitly applicable solution to a problem, is an accepted research paradigm in other disciplines, such as engineering, it has been employed in just a small minority of research papers published in our own best [information systems research] journals to produce artefacts that are applicable to research or practice." To solve this dilemma, Peffers et al. propose a design science research methodology (DSRM). Its aim is to establish a commonly understood framework, so that design science research in Information Systems is more easily "accepted as valuable, rigorous, and publishable in Information Systems research outlets" instead of needing to justify "the research paradigm on an ad hoc basis with each new paper". The DSRM framework follows the six guidelines for conducting well carried out Design Science (DS) research provided by Hevner, March, Park, and Ram (2004). These guidelines form the basis for further structuring the retrospective perspective and considerations of this article.

# PKM versus Design Science Research Guidelines

Hevner et al. (2004) motivate their DS research guidelines (Table 2) also as a reaction to the lacking impact of information systems research on business practices or organizational capabilities and to the unsuitable presentations already alluded to. Their aim is to supplement the reactive behavioral (natural) science paradigm with the proactive design science paradigm in order to support information technology (IT) researchers in creating innovative IT artefacts that extend human and social capabilities and meet desired outcomes. However, since "simply creating a new IT artefact for extant organizational problems does not necessarily constitute good research" (Hevner et al., 2004, p. 2), the guidelines are meant to provide a roadmap for conducting and criteria for evaluating DS research in IT. In the context of this article, their intended purpose is applied to the PKM project.

## *PKMS Design as a Set of Novel Artefacts (G1)*

March and Smith (1995) differentiate research outputs according to instantiations, models, methods, and constructs. The prototype system-in-progress represents the *major instantiation* of the PKM concept as the realization of a novel working *world:1/technology* IT artefact rooted in the personal, educational, and professional environment of knowledge societies. Its aim is to demonstrate the feasibility and effectiveness of the underlying models, methods, and constructs which operationalize the *world:3/ideosphere* 'big-T theory'. *Supporting further instantiations* include *world:1* 'small-T theories' in form of the publications and presentations alluded to.

| Table 2. Design Science Research Guidelines (Hevner et al., 2004) | | |
|---|---|---|
| # | Guideline | Focus Area |
| G1 | Design as an Artefact | The designed artefact (e.g., construct, model, method, or instantiation) must be effectively represented, enabling evaluation and comparison with existing artefacts created for the same purpose as well as enabling implementation and application in an appropriate environment to demonstrate *feasibility*. The critical nature of DS research in IS lies in the identification of new IT capabilities, resulting in the expansion into new realms with significant impact. |
| G2 | Design as a Search Process | Effective design requires knowledge of both the application domain (e.g., requirements and constraints) and the solution domain (e.g., technical and organizational). Due to the complexities involved, effective problem solutions benefit from systematically utilizing *heuristic search strategies*, including decomposition, abstraction, analogies, and iterative and incremental approaches with no well-defined stopping rules. |
| G3 | Problem Relevance | Purposeful IT artefacts are created, applied, assessed, and improved to address important and relevant heretofore unsolved problems by supporting the practitioners who plan, manage, design, implement operate, and evaluate the resulting information systems and/or their outputs. Criteria for assessing relevance focus on *representational fidelity* and *implementability*. |
| G4 | Research Rigor | DS is a creative and often iterative problem-solving process which has to make effective use of the DS theoretical foundations and methodologies. A construction and evaluation of a design artefact need to be based on rigorous methods (e.g. empirical methods, mathematical formalism, or deductive logic). Rigor must be assessed with respect to the *applicability* and *generalizability* of the artefact and its *performance metrics* within the overall human-machine problem-solving system. |
| G5 | Research Contributions | Effective design science research must provide clear contributions in the areas of the design artefact, design construction knowledge (theoretical foundation), and/or design evaluation knowledge (evaluation methodologies). |
| G6 | Design Evaluation | A design artefact is complete and effective (*utility*) when it satisfies the requirements and constraints (*functionality*) of the problem it was meant to solve (*performance*). Its quality and efficacy must be rigorously demonstrated via well-executed evaluation methods. Good designs embody a style that is aesthetically pleasing (*elegance*) to both the designer and the user (*usability*) and that fits with the technical infrastructure of its environment (*consistency, accuracy, reliability*). Design evaluation includes observational, analytical, experimental, and testing methods. |

*Models* are representations of how things are or how they ought to be, while *Methods* are sets of steps (guidelines or algorithms) to be taken to perform a task. Over a hundred renowned models and methods have been incorporated in the PKMS design including their adjusting, extending, repurposing, or merging. In the process, a set of enriched or novel models have been coined and visualized, including a comprehensive three-dimensional Information Space depicting the internal and external PKM environment, the Digital Ecosystems and its Complexity Framework, an Extended Ignorance Matrix, a PKM Value Chain, a PKM for Development Framework, and a Dynamic Meme Reuse and Modification Model. Most of these models are represented as transparent maps able to integrate and depict methodological sequences of processes and events, including cycles of learning and waste, foraging and sensemaking loops.

*Constructs or Concepts* form the specialized language and shared knowledge of a particular domain or problem environment. However, as a support tool for life-long learning (Schmitt & Butchart, 2014) and as an "Artefact and Expediter of Interdisciplinary Discourses" (Schmitt, 2015g), the PKM concept and system strive towards multi- and transdisciplinary applicability. To promote this aspiration, the publications (Schmitt, 2012-2016) have been disseminated to and received feedback from a wide range of disciplines via journal and conference submissions covering Knowledge Management and Information Science, Technologies and Innovation, Social Sciences and Management, Human Resource Development and Organizational Change, Higher Education, Sustainable Development, Creativity, Cybernetics, Systems Thinking, and Future Foresight. The scope of language and knowledge is further broadened by integrating concepts of evolution and memetics as well as by engaging in KM's extensive use of analogies and metaphors.

Stringently defined – in contrast – are the types of entities and dynamic relationships which govern the structure and operations of the PKMS knowledge base. Able to represent *world:2* ideas and *world:1* objects and classifications as well as their higher-order combinations (e.g., documents, authorship, ownership, organizational structures), the novel PKMS devices facilitate the features of Bush's 'Memex' envisioned seven decades ago. They act as enlarged intimate supplements to our memory and enable us to store, recall, study, and share the "inherited knowledge of the ages" relevant to us. They facilitate the addition of personal records, communications, annotations, contributions as well as non-fading trails of our individual interest through the maze of materials and memes available (Associative Indexing): all to be easily accessible and shareable with the PKMSs of acquaintances. As a consequence, the traceability of knowledge significantly improves, since "the inheritance from the master becomes, not only his additions to the world's record, but for his disciples the entire scaffolding by which they were erected" (Bush, 1945).

## *PKMS Design as an Iterative Heuristic Search Process (G2)*

*World:3/ideosphere* 'big-T theories' and their respective *world:1* 'small-T theories' must be closely fitted to an author's *world:2* vision and firmly rooted in observations and understandings of *world:1/technology & extelligence*. They also must be carefully and methodically crafted to meet utility and communication expectations. All design elements are closely interrelated and any change in one area inevitably elicits effects on all the others. The high level of complexity in the solution domain is further heightened by the diversity of scholarly work in KM's interdisciplinary application domain.

The design of a PKM system fits into the category of so-called "wicked" problems, defined by Rylander (2009) as open-ended in the sense "that they are ill defined and characterized by incomplete, contradictory, and changing requirements and complex interdependencies and that the information needed to understand the problem depends upon one's idea for solving it." To solve such a problem, Stanford's D-School (2015) suggests an iterative process approach of empathizing, defining, ideating, prototyping, and testing.

However, particular to this PKMS-related case and its design cycles has been that the client, user, analyst, designer, and developer roles all reside in the one person of the author. The steps taken as part of each of the iterative design cycles have been adapted accordingly and have resulted in the A-B-C-D-E-F Steps which define any of the individual cycles within an iterative PKMS Design Process (Figure 5) to be introduced below.

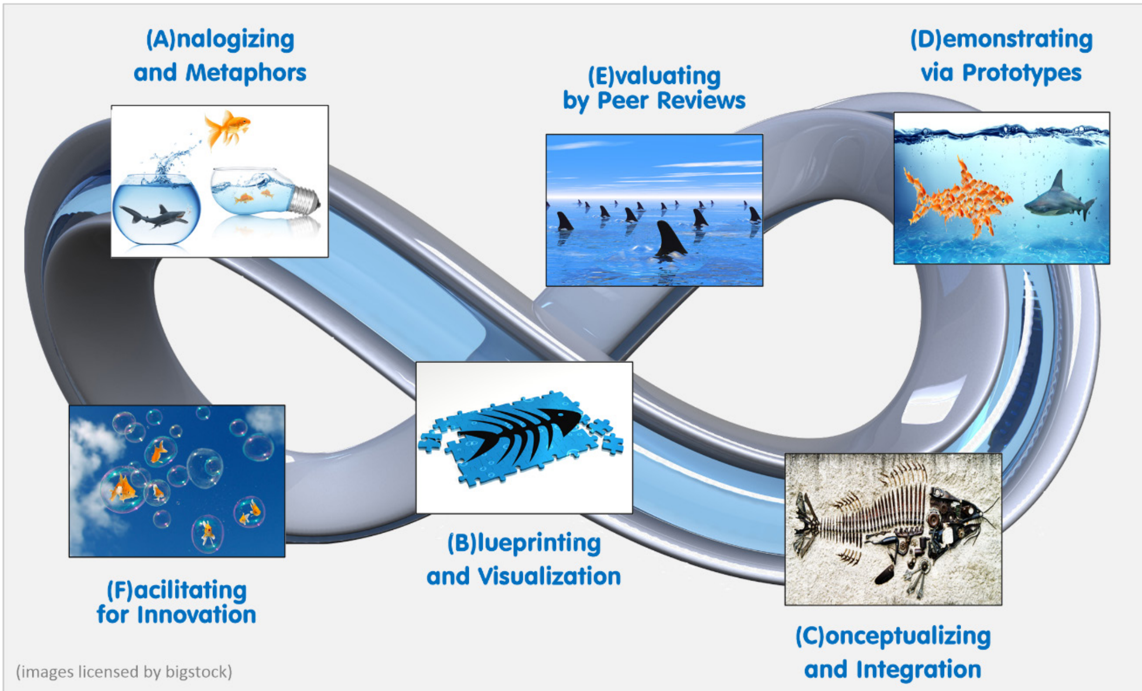


**Figure 5. A-B-C-D-E-F Steps of any Single Cycle in the Iterative PKMS Design Process**

## Step A: Analogizing and metaphors

Knowledge and its management are abstract concepts with no clearly delineated structure and no 'real world' referent. To apply structure and make them comprehensible requires the mapping of familiar notions of other disciplines to the one to be illuminated by means of analogical thinking and graspable metaphors. By, for example, analyzing two classic chapters in the KM literature, Andriessen (2006) detects twenty-two metaphors able to populate alternative continuums from physical to abstract, from tangible to intangible, and from static to dynamic knowledge. Similarly, the first step of each phase determines the adequate metaphors on which subsequent considerations are based.

## Step B: Blueprinting and visualization

The management of knowledge is governed by an ill-structured mishmash of complementing as well as conflicting interdisciplinary methodologies and based on physical and social technologies which too often struggle to achieve their stakeholders' objectives due to diverse scholarly contributions, repetitive polemic discourses, and misguided organizational system generations. To facilitate understanding, the portrayal of potential better solutions cannot be accommodated by one-dimensional linear text alone but necessitates the utilization of visuals, charts, and blueprints for the concept as well as the use of colors, icons, and catchy acronyms to support the human-computer-interaction of the final system.

## Step C: Conceptualizing and integration

The 'write-only-after-you-can-picture-it' advice also includes the successful navigation of the intrinsic complexities mentioned. The quest for an all-embracing high-level system concept and design has to unearth feasible solutions in regard to the many methodologies advocated by scholars and practitioners. Fortuitously, what might have appeared initially as difficult to reconcile or at odds (e.g., KM's objectives, philosophies, and methods) has been integrated into sub-systems serving an overarching system architecture, covering the over one hundred renowned KM models and methods mentioned earlier.

### Step D: Demonstrating via prototypes

The conceptualization of the sub-systems and their interfaces has to be validated by the programming of adequate knowledge base structures, workflows, and user interfaces. Since one of the PKMS objectives is to support authorship, the own and cited ideas and memes constituting the PKM-related papers published also form the test data for the PKMS functionalities and repository. The familiarity with the content and how it is related eases evaluating the test results as well as any reconfiguration of knowledge base structures or workflows prompted by subsequent design decisions to adjust or add system functionalities.

### Step E: Evaluating by peer reviews

With a prototype system in a continuous flux of development, the feedback from publications becomes a major determinant of quality assurance with the peer reviewers and audiences unconsciously taking up the role of an extended multi-disciplinary development team. In line with the interdisciplinary nature of the PKMS, the publications at the wide disciplinary range of conferences and journals assure a diversity of feedbacks. The approach also allows for further inspiration by attending other delegates talks and peer-to-peer discussions.

### Step F: Facilitating for innovation

Although this step predominantly features in the last phase prior to the marketing and distribution of the final product, many related activities can be addressed earlier. With the papers captured in the PKMS repository and the individual publications pitched at particular contexts of analogies, blueprints, and sub-concepts, any content can be easily repurposed for presentations as an individual book chapter and face-to-face or e-learning course unit. This captured knowledge also provides the means for the PKM system's help and tutorial functions as well as the initial stock of PKMS knowledge bases providing content to be potentially integrated into users' own publications. Terms, color schemes, icons, logos, slogans, and trademarks are also (pre-)determined in the earlier phases easing the subsequent tasks of creating business and communication plans, funding or cooperation proposals.

## *PKMS Relevance Serving Communication and Utility (G3)*

While envisaging a potential KM revolution that gives more power and autonomy to individuals and self-organized groups, Levy (2011) suggests a personal discipline for collection, filtering, and creative connection (among data, among people, and between people and data flows) and regards the sustainable growth of autonomous capacities in Personal KM as the most important function of future education. Wiig (2011), as pointed out earlier, recognizes the PKM root objective as the desire to make citizens highly knowledgeable. The quality and extent of individuals' competences and the structural Intellectual Capital (IC) assets available to them determine the realized performance of enterprises and societies. By the same token, Bedford (2013) expects KM education to provide the key opportunities for growing a 21st century knowledge society, just as business, engineering and science education still do for the industrial economy.

Already, the spheres of work and careers have changed dramatically (Florida, 2012; Gratton, 2011; World Bank Institute, 2008). In parallel, an uneven diffusion of digital technologies has caused detrimental opportunity divides across societies worldwide (Drori, 2010; Giebel 2013; Johri & Pal 2012). "It is [now] crucial that all countries, large and small, rich and poor, take advantage of science, technology and innovation as fundamental elements for their development strategies, poverty reduction and the construction of a Knowledge Society" (OAS, 2005). 'Future of Employment' studies (Bowles, 2014; Frey & Osborne, 2013) still estimate that half of today's employment (US and EU) is at risk due to the emerging 'Industrial Internet' (Evans & Annunziata, 2012) and due to recent technological breakthroughs able to turn previously non-routine tasks into well-defined problems susceptible to computerization. An impact of this magnitude would necessitate a reallocation of workers towards tasks less susceptible with the likely prioritization of creative and social intelligence.

Individual, institutional, and societal pressures for greater flexibility and skill sets are clearly set to further grow. Extelligence, however, only generates competitive advantage if it is accessible and augmentable by individuals who know how (Stewart & Cohen, 1999). Personal and organizational life would have been so much easier, if Bush's seven decades old vision of the 'Memex' had materialized already (Bush, 1945; Davies, 2011; Kahle, 2009; Osis & Gaindspenkis, 2011).

But, so far, KM initiatives have been pre-dominantly enterprise-based. They view knowledge as a foremost strategic asset to be measured, captured, stored, and protected. Complementing this technology-dominated first generation, a more practice-based and community-centered approach has emerged as a second phase in the last decade characterized by social media and the cloud (Schmitt, 2015f). On the one hand, this adjustment is owed to the ICT-related organizational, commercial, social, and legal innovations alluded to. On the other hand, it is due to too many KM initiatives not delivering on their promises (Frost, 2013; Malhotra, 2004; Pollard, 2008; Schuett, 2003; Wilson, 2002). Due to the deficiencies experienced, an experts' consensus about focal points for the 'Next KM' generation seems to be emerging: the "Use of Existing and Creation of New Knowledge" and the "Personal and Social Nature of Knowledge" (K. A. Grant & Grant, 2008). A recent study among 222 KM experts worldwide confirms these trends (Heisig, 2014) and its IT-related findings stress the growing importance of enabling interactive KM technologies and research priorities of combining human and technological factors, of effectively using appropriate tools and systems, of focusing on practical relevance, and of being able to predict the benefits and risks of 'the next big thing' rather than merely presenting retrospective deliberations (Sarka, Caldwell, Ipsen, Maier, & Heisig, 2014).

The PKM concept proposed, the prototype-system-in-progress, the currently over thirty publications together with their envisioned book, tutorial, and coursework 'spin-offs' address all these pertinent problems by addressing educational and professional needs and by tackling opportunity divides independent of space (e.g., developed/developing countries), time (e.g., study or career phase), discipline (e.g., natural or social science), or role (e.g., student, professional, or leader).

## PKMS as Rigorously Systemic/Systematic Design Process (G4)

The references to the prior work of other authors in this article represent just a subset of the combined publications' bibliography; they exemplify the inter-disciplinary relevance and coverage as well as the rigor with which prior relevant scholarly contributions and current empirical findings have informed and shaped the PKM-related research and design processes. After several iterative cycles of the A-B-C-D-E-F steps portrayed (figure 5), the multi-disciplinary substantial feedback from audiences and peer reviewers has helped consolidating the work presented to aid a systemic PKMS approach across disciplinary boundaries. The steps and cycles also allowed for the incremental adjustments of the overall 'big-T theory' in a systematic and coherent manner and for adapting and fine-tuning the plans for the roads ahead.

"Scholarship is an inherently social activity, involving a wide range of public and private interactions within a research community. Publication, as the public report of research, is part of a continuous cycle of reading, writing, discussing, searching, investigating, presenting, submitting, and reviewing. No scholarly publication stands alone" (Borgman, 2007). In the PKMS context, the notion of '*Standing on the Shoulders of Giants*' is following four major motivations.

Firstly, "although the novel PKMS concept aims at departing from the centralized institutional developments and at strengthening individual sovereignty and personal applications, it is not meant to be at the expense of Organizational KM Systems, but rather as the means to foster a fruitful co-evolution" (Schmitt, 2014k, 2016g). This aim is based on mutually beneficial interests of PKM–OKM-users in collectively harvesting prior accumulated knowledge subsets and in converting individual into organizational performances. This endeavor requires a solid *common ground of renowned and accepted KM methodologies and practices* (Schmitt, 2015b, 2015f, 2016d).

Secondly, the KM-relevant record available (as further portrayed under Step B) is governed by an ill-structured mishmash of complementing as well as conflicting interdisciplinary methodologies. Establishing a common ground necessitates not only a stringent evaluation and selection of the many solutions advocated by scholars and practitioners, but frequently requires their adjustment, extension, re-purposing, or merging in order to proceed towards an *integrated KM system architecture*. For example, the Personal Knowledge Management for Development (PKM4D) framework, briefly mentioned in the introduction, has been one of the outcomes in this endeavor. It breaks down the features of the PKM approach into twelve distinct benefits for individuals, but also points out the negative effects if support for any of the sub-features is not available (Schmitt, 2014k, 2015a, 2016h). As a tool closely interrelated with Maslow's Extended Hierarchy of Needs, the PKM4D framework also provides the basis for cross-referencing the personal sphere of the individual with the educational, professional, organizational, and developmental spheres at an institutional level. Not only can the *applicability* and *generalizability* of the PKM System in the relation to individual Knowledge Workers be differentiated and demonstrated, they also can be assessed, aggregated, and compared with other support scenarios to assist in the developmental context of businesses and agencies.

Thirdly, to *quality assess and assure the PKMS design*, its processes have been validated against established concepts and methodologies (Schmitt, 2013c, 2013g, 2014a, 2014e, 2015a, 2016c) including 'Mapping of the Agent and the World' (Boisot, 2004), 'Intelligence versus Extelligence Concept' (Stewart & Cohen, 1999), 'Notional Model of the Sensemaking Loop for Intelligence Analysis' (Pirolli & Card, 2005), 'SECI-Spiral' (Nonaka & Takeuchi, 1995), 'Eight Building Blocks of KM' (Probst, 1998), 'Creative Space' and 'Seven Waterfall Model' (Wierzbicki & Nakamori, 2006, 2007). A recent article (Schmitt, 2015d) employed the systems thinking techniques of the transdiscipline of Informing Science (IS). By applying the IS-Framework and the IS-Meta Approach (Cohen, 1999, 2009), the Change (Diamond) Model (Leavitt, 1965), and the Design Task Complexity Model (Gill & Murphy, 2011), the more specific KM models and methodologies central to the PKM system concept were aligned, introduced, and visualized.

Fourthly, a PKMS merges distinctive knowledge objects/assets of diverse disciplines into a single unified knowledge repository. In following the PKMS concept's aim to contribute to educational development, all PKMS publications and their references already form part of the prototype's knowledge repository. Their meme-based representations are based on – as Bush (1945) put it – "an extensive mesh of associative multidisciplinary trails already built-in of alternative pathways" which can be handily tracked and further explored by a PKMS user community to become subsequently part of their own contributions to PKMS repositories. This mesh facilitates associative indexing which will also conveniently accommodate the establishment and navigation of PKMS e-learning modules planned following the face-to-face course design. Moreover, the integration of the over two hundred KM tools and ideas into the PKMS concept allows for *KM education in a transparent and coherent manner*, including the rationale how and why some of the original methods had to be adjusted, extended, re-purposed, or merged.

## *PKMS as Research to Innovate Knowledge Management (G5)*

Many of the envisaged benefits of the PKMS concept and implementation have been explicitly and implicitly referred to in the previous sections. Following a *personal* (rather than organizational), *bottom-up* (instead of top-down), *meme-based* (complementing document-centric), and *creative-conversation-focused* (versus fragmented and silo-prone fixated) approach introduces an innovative constellation to the KM domain and technologies. Its novel methodologies and features have been detailed in respect to overcoming current constraints and barriers (Schmitt, 2014b, 2014f) and to their potential to change personal (Schmitt, 2015d), organizational (Schmitt, 2015c, 2015f, 2015i), and societal (Schmitt, 2015a, 2016h) KM perspectives and practices. Due to this change potential, it also has been looked at from the perspective of Kuhn's ideas (1970) related to paradigms and scientific revolutions (Schmitt, 2015d), from the point of view of general-purpose-technologies (Schmitt, 2015h), and disruptive innovations (Schmitt, 2016g). With references to the theoretical foundation also made and with the evaluation methodologies to follow, this sub-section attempts to provide a bird's eye three world view to add a high-level strategic perspective to these considerations. It is informed by the complexity dimensions introduced earlier (Figure 3) in order to focus on unsustainable developments and opportunity divides.

A prior paper (Schmitt, 2014b) argued that human progress can be attributed to five co-evolutions which effectively dealt with successive emerging constraints at their respective stages (Figure 6):

- Embodied and embrained knowledge were the results of a gene-brain-co-evolution propelled by ever more creative memes (Dawkins, 1976; Distin, 2005); Koch, 2001).
- Encapsulated and encultured knowledge stem from the notion of physical and social technologies supported by ever more complex plans (Beinhocker, 2006).

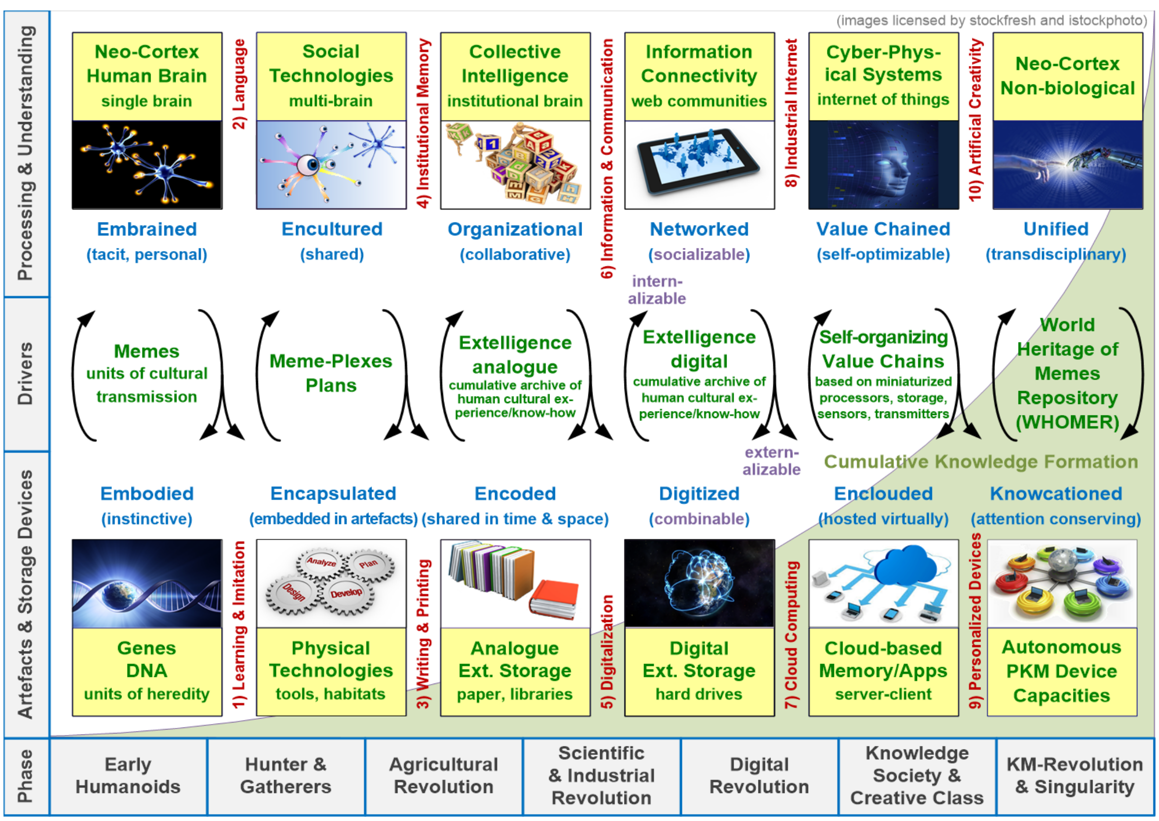


**Figure 6. Five Co-evolutions shaping Human Progress and a possible Scenario**
(Schmitt, 2014b)

- Encoded and organizational knowledge required external storage devices (analog) and collective intelligence backed by accumulating extelligence (Stewart & Cohen, 1999).
- Digitized and networked knowledge needed digital external storage devices and information connectivity built up by mounting digital extelligence.
- Enclouded and value-chained knowledge is about to take the center stage based on cloud-based memory and applications linked to cyber-physical systems and self-organizing value chains driven by the growing generation and impact of big data.

Putting it in Popper's terms, a recurrent pattern of emerging limitations (*World:1* physical artefacts and storage devices) imposed constraints on human intermediaries (*World:2* processing and understanding) to further advance the world's accumulated record (*World:3* knowledge object drivers) for feeding wide-scale technological progress (*World:1* physical object innovations).

Only particular general-purpose technologies (language, writing, printing, record keeping, digitization, ICT, cloud, and industrial internet) were and will continue to be able to overcome these constraints (Figure 3), often only after profound periods of stagnation and disorientation exaggerated by ignored synergies of emerging properties and neglected needs to abandon lock-ins, shift paradigms, change habits, and innovate. But, in terms of constraints, the pattern has changed.

The dominant bottleneck is no longer the limitation of *world:1* objects but the ever-increasing abundance of a particular type of objects, like books, web content, digital records, or documents (to which this article contributes). It means that *world:2* processing and understanding is not any more hampered by the scarcity of *world:1* sources and content available but by their sheer ever-increasing numbers and volume (Hilbert, 2011, 2014; Short et al., 2011) which overload the *world:2* finite scarce human attention capacity available[5]. This currently unsolved and unsustainable situation can be summarized by paraphrasing Popper (1978): With the *world:2* mind short-changed of a thorough grasp of the *World:3* knowledge due to overwhelming *world:1* object redundancy, fragmentation, inconsistency, untraceability, corruption, and decay, the *World:2* power for *world:3* innovations and *World:1* change is diminishing at a disturbing rate (figure 7).

The new bottleneck's inefficiencies and contributing barriers have been identified (Schmitt, 2014f) and the PKMS design thinking process circumnavigated four iterative A-B-C-D-E-F design cycles (Table 3[6]) to propose a solution able to escape the current lock-in situation.

The solution proposed by the PKMS concept follows three central leitmotifs:

- If memes and their inbuilt ideas are able to flourish in a virtual 'Ideosphere' as their habitat of operation, PKM Systems aiming at supporting individual capacity and repertoire for innovation, sharing and collaboration are well advised to utilize the very same space and resources and to form a digital counterpart of this 'Ideosphere' (Schmitt, 2014l, 2016a).

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[5] In 'Designing Organizations in an Information-rich World', Simon (1971) pointed out that the "wealth of information creates a poverty of attention and [with it] a need to allocate that attention efficiently among the overabundance of information sources that might consume it". Thus, "it is not enough to know how much it costs to produce and transmit information; we must also know how much it costs, in terms of scarce attention, to receive it. […] In a knowledge-rich world, progress does not lie in the direction of reading information faster, writing it faster, and storing more of it. Progress lies in the direction of extracting and exploiting the patterns of the world – its redundancy – so that far less information needs to be read, written, or stored".

[6] Attentive observers will notice that the chronology of publications does not strictly match the sequence of the iterative cycles presented. The justification for these a-synchronous timelines has been the author's ambition to give some earlier conceptual ideas the time to mature sufficiently, in regard to the compatibility to parallel conceptual developments as well as to the distinctive terms (in the overall PKM system context) to be applied for their dissemination. From today's point of view, this course of action has paid off since only a minor number of aspects reported in earlier papers had to be revised.

- If the overall performance and viability of societies and enterprises result from innumerable small actions by individuals, from the quality and extent of their competences and the structural Intellectual Capital assets available to them, then – as a prerequisite – people must also be provided with the resources and opportunities to do their best (Wiig, 2011).
- If the future of work and knowledge societies is based on the notion that knowledge and skills of a knowledge worker are portable and mobile, then individuals moving from one project or responsibility to another, ought to be able to take their version of a knowledge management system with them – as laid out in the six PKMS provisions (Schmitt, 2015i).

| **Table 3. Overview of the Iterative PKMS Design Process Cycles** | |
|---|---|
| 1 | *One's Personal Motivations, Burdens, and Obstacles:* Having explored the challenges and motivations as described in the PKM4D framework, the broader aims of the PKMS were defined. The farming metaphor describes a PKMS space, where prior knowledge will provide the potentially limitless soil, learning and research the life-spending water, own new memes and ideas the fertilizer, re-combinations and mutations the farm work, collaborators' and supervisors' memes the helping hands, publications and presentations the crop, and the shared harvest is represented by knowledge dissemination leading to adaptations, co-operations, and innovations. The digital PKM quartermaster will guard the fruits and show the way for mastering the interdependent and iterative cycles. However, several technological and market barriers were identified which explain the current absence of PKMS devices which led to specifying six vital provisions or pleas for their establishment. |
| 2 | *One's Knowledge-related Playing Field:* As a basis for many of the subsequent blueprints, Boisot's three-dimensional Information-Space Model has been adopted. Its role is to visualize the integration of several KM methodologies as well as the workflows of the PKMS system and to position relevant knowledge types and assets. As a result, a map of the 'Ideosphere' emerges including 'ba' as the 'spaces' where thoughts, theories, and ideas evolve and are communicated, documented, and utilized via foraging and sensemaking loops. |
| 3 | *One's Knowledge-related Capitals to develop:* Knowledge workers are advised to develop their skills and competencies as well as their intellectual, social, and emotional capitals. The related tasks, entities and learning cycles had to be clearly specified for integration into the PKMS's 'Ideosphere' and 'Spaces' concept. But, knowledge is a perishable good threatened by becoming forgotten or outdated. Accordingly, the extension of the ignorance matrix attained central importance in blueprinting the value chain connecting PKMS users with the 'Ideosphere'. The notion of memes acquired similar status: If memes and their inbuilt ideas are able to flourish in a virtual 'Ideosphere' as their habitat of operation, PKM Systems aiming at supporting individual capacity and repertoire for innovation, sharing and collaboration are well advised to utilize the very same space and resources and to form a digital counterpart of this 'Ideosphere'. |
| 4 | *One's Contributions to the Progress of the World:* Knowledge is socially constructed. On the one hand, we are the beneficiaries of the performance of others, of organizations and society; on the other hand, we are also meant to contribute. Accordingly, this phase examines the potentials of creative conversations by PKMSs collaborating with other PKMSs or organizational KMS. It assesses the possible impact supported by a proposed central 'World Heritage of Memes Repository (WHOMER)' on scholarship, interdisciplinary discourses, knowledge traceability, and reputation-based citation systems. It further validates the PKMS concept against the Information Science and Design Task Complexity Frameworks, evaluates it in the context of human civilization, general-purpose technologies, disruptive innovations, and scientific revolutions, and introduces the meta-levels of Popper's Worlds, Digital Ecosystems, and the UN's scenario of Knowledge Mass Production. |

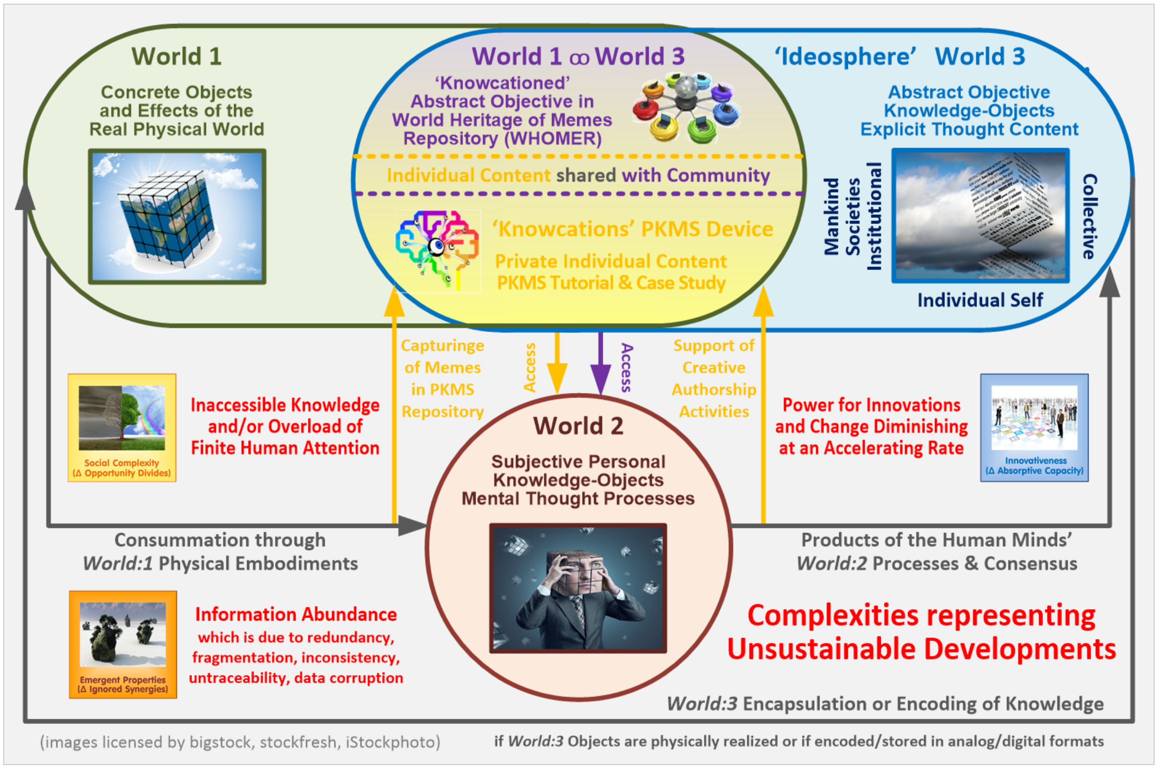


**Figure 7. Popper's Three Worlds represented with the added hybrid PKMS Instantiation**

The solution incorporates the functionalities of two distinctive artefacts (Figure 7):

- Firstly, personal PKMS devices – named '*Knowcations*' – support individual's sovereignty and autonomy by employing grass-roots, bottom-up, affordable, personal applications. They aim to put an end to the detrimental dependencies experienced as members of current providers' 'captured audiences' and signify a departure from today's top-down, heavy-weight, prohibitive institutional approaches and centralized developments. Accordingly, digital personal and personalized knowledge stays always in the possession and at the personal disposal of its owner or eligible co-worker – based on standardized, consistent, transparent, flexible, secure, and non-redundant formats as well as independent of changes in one's social, educational, professional, or technological environment.
- Secondly, a '*World Heritage of Memes Repository (WHOMER)*' unlocks collaboration capabilities between the decentralized autonomous PKMS devices and voluntarily shared parts of their knowledge base capacities. Sharing one's memes and meme relationships and accessing those shared by others, facilitate the "emergence of distributed processes of collective intelligence, which in turn feed them" (Levy, 2011). Collaboratively interlinking these personal human capitals to collectively trace, harvest and utilize accumulated knowledge subsets will overall reduce redundant content and improve productivity of information seekers and suppliers alike.

Thus, nourished by the creative user conversations of many individuals' personal knowledge management, the networked 'Knowcations' and 'WHOMER' devices establish continuous feedback loops allowing the tracing, reusing, and/or repurposing of collective knowledge and ideas. The result is depicted (Figure 7) as a newly configured world (w:1 ∞ w:3) made up of abstract objective *world:3* knowledge objects after undergoing a once-off *world:1*-type concretization exercise in order to become a unique permanent unalterable 'WHOMER' meme resident. For updates, shared links to modified successors are integrated from PKMS devices subsequently. For further creative connections, shared links to any other meme (associative indexing, e.g. reference to prior works, prior or subsequent meme in writings, figures, footnotes, annotations, keywords, relevant topics, standards, relations to people or domains) are integrated likewise. Shared user activities are further supported by WHOMER's curation, knowledge, search, traceability, metrics, and educational services, all aimed to overcome the redundancy, the perishability, and potential fallibility of current online knowledge, services, and providers (Schmitt, 2015c, 2015i).

## *PKMS as a Stream of Comprehensive Design Evaluations (G6)*

To briefly summarize: From the project's academic perspective, the author's *world:2* PKMS vision – based on the analysis of the current *world:1/technology & extelligence* constraints and inadequacies – has been transformed into a *world:3/ideosphere* 'big-T theory' and – since September 2012 – resulted in over thirty *world:1/extelligence* 'small-T theories' in the form of *world:1/technology* posters, conference papers, journal articles, prototype demonstrations, and tutorials. One of these publications is titled "How this paper has been created by leveraging a personal knowledge management system" (Schmitt, 2014d). However, not only this paper but all publications are captured in the (*w:1∞w:3*) PKMS knowledge base in order to provide a realistic 'big-T/small-T' sample set of non-redundant memes for suitable test scenarios and real-life case studies.

While some design evaluation methods – based on the meme sample sets captured – have already been applied during the iterative cycles, other are in progress or planned. This sub-section briefly refers to the methods mentioned earlier and adds further details about evaluations projected or not yet completed. After completing the test phase of the prototype, its transformation into a viable PKMS device application and a cloud-based WHOMER server based on a rapid development platform and a noSQL-database is estimated to take 12 months.

### Analytical Design Evaluations

- *Static Analytical Methods* have been applied by positioning the PKMS features and envisioned outcomes against Gill's and Murphy's (2011) Design Task Complexity as well as the systems thinking techniques of Informing Science (Schmitt, 2015d). The envisioned impact has been looked at in the context of Kuhn's Scientific Revolutions, General-Purpose-Technologies (Schmitt, 2015d, 2015g), disruptive innovations (Schmitt, 2016g) and affordances and fixations (Schmitt, 2017). Newly devised PKMS methods and processes have also been benchmarked against their traditional counterparts (e.g., PKMS workflow against Foraging and Sensmaking Loop, PKM4D framework vs. Pyramid of Needs, or extension of the Ignorance Matrix).
- *Dynamic Analysis Methods* are in progress by comparing the metrics of the PKMS publications meme sample set with its document-centered representation as provided by Google Scholar and ResearchGate. Further 'life' demonstrations are also planned (Schmitt, 2014i).
- *Technical IS Architecture Analysis* has been carried out on a continuous basis. It has been clear that the current windows-based RDBMS environment of the prototype system in inadequate for the intended purpose. Nevertheless, setting up the logical and knowledge base structures with the imminent migration in mind has been possible. Meanwhile, a rapid development platform has been acquired and a suitable no-SQL database has been selected.

### Experimental Design Evaluations

- *Simulation with Artificial and Real-Life Data:* The PKMS knowledge base and functionalities have been populated and tested with a variety of data sets, including, for example, the PKMS publications with their references; personal contact bases and libraries; personal chronological biographies and family trees; cocktail database; directories of journals, universities, cities, regions, and countries; 'Excellence in Research for Australia (ERA)' database sets; industrial classification systems; standards, criteria, and self-assessment for MBA accreditation.

- *Controlled Experiments* have been carried out by preparing and authoring new publications and presentations based on the memes and their relations captured in the PKMS knowledge base, as in case of the paper titled "How this paper has been created by leveraging a personal knowledge management system" (Schmitt, 2014d). While a paper comparing the novel meme-based PKMS approach to current semantic and ontology-based developments is in progress, a further experiment is planned to assess the potential of the PKMS to also publish the memes and relationships in its knowledge bases in the format of formal knowledge representation languages.

### Testing and Observational Design Evaluations

- *Functional (Black Box) Testing* has been going on continuously in line with the iterative design cycles prompted by adding functionalities and flexibilizing user interfaces and interactions. *Structural (White Box) Testing* has been performed – in particular – in respect to database structure modification. Having started with a complex multi-table entity-relationship-structure, the number of tables has been successively reduced by consolidating their record structures and by using self-referencing within tables now containing diverse record sets. With migration to the new rapid development platform and the no-SQL database these testing efforts have to be intensified.
- Further testing is planned in the context of a *Field Study*. It will take place as part of the PKMS tutorial or lecture and the students will be asked to do their assignments based on their PKMS device. Similar tests were performed some time ago with a much simpler PKMS version where students had to do their assignments about the purpose and procedures of selected business methods in the meme-based format to be subsequently shared among the cohort members.
- These field studies are planned to be incorporated in an *in-depth analysis* of the PKMS concept and devices in respect to their educational and organizational impact, including the typical usability and satisfaction surveys and resulting statistics leading to further *empirical research reports and case studies*.

## *Presenting Design Science Research to a Diverse Audience (G+)*

Since a PKMS embodies many entities with inherent multi-dimensional structural interdependencies, the complexity of the tasks to be handled by a user needs to be sufficiently eased by intelligible concepts and well thought-out design features. The vision communicated, meme-concept applied, functionalities offered, and tangibles provided are therefore aiming to mobilize and motivate the relevant audience and instill in them a sustainable commitment to endorse and interact with the PKMS technologies on a continuous basis in order to keep personal human capitals à-jour and to reap the potential benefits.

Mostert (2013) describes Six Levels of Appreciation in the context of leadership development. However, they are equally applicable to potential PKMS users. The model starts with just appreciating the idea of the proposed system (aesthetic elegance creates curiosity), followed by recognizing a close match with one's own views (schematic resonance adds validity), and then with one's own experiences and needs (contextual relevance adds significance). At the fourth level, the added value towards one's own circumstances is realized (opportunity based on utility), followed by making it a personal priority (responsibility for advancement), with the final stage of successful implementation and utilization (enactment). However, to keep 'enacting', the added values generated for the user will have to significantly outstrip the user's perceived inconveniences due to time, effort, and self-discipline invested.

These added values have been detailed in the PKM4D framework. It builds upon the Information and Communications Technology for Development (ICT4D) notion suggested by Johri and Pal (2012) to not only focus on making effective low-cost applications available (accessibility easiness), but to enable authorship and contribution of own ideas based on one's background (expressive creativity), alone or in collaborative environments with other users/owners (relational interactivity), and with the opportunity to add productively to the world's extelligence (ecological reciprocity). The establishment of the World Heritage of Memes Repository (WHOMER) strengthens these benefits and the further eight PKM4D criteria and eases creative conversations, but also reduces inconveniences by enabling simplified access to digital extelligence shared by others.

In anticipation of the conversion of the prototype into a commercially viable cloud-based application with subsequent deployment, the focus of the upcoming papers and presentations has shifted to innovation, entrepreneurship, and the synergies with Learning Management Systems (LMS).

# Conclusions

By contemplating the past, present and possible futures of design thinking, Johansson-Sköldberg, Woodilla, and Çetinkaya (2013) differentiate between the professional-design oriented '*designerly thinking*' and its newer simplified management-oriented '*design thinking*' approach. They categorize the former into five sub-discourses with an emphasis on the creation of artefacts, on reflective practices, on problem-solving activities, on ways of reasoning and making sense of things, and on the creation of meaning. The development of the PKMS involves all five discourses and its aim is to create an artefact which, in turn, also supports all five discourses as the means for life-long-learning, resourcefulness, creative authorship and teamwork throughout an individual's academic and professional life and for his/her role as contributor and beneficiary of organizational and societal performance. A current paper-in-progress also demonstrates the PKMS's constructive support of Usher's (2013) concept of 'Cumulative Synthesis', a process-oriented performative account of innovation.

From the *Design Science Research*, perspective, the article expands the reflections on the PKMS research paradigm further into the realm of Information Systems. Aimed foremost at a researchers' rather than a technical or managerial audience, it deals with the implementation and organizational PKMS details by referring to the dedicated prior publications and, instead, focuses on the process, relevance, rigor, evaluation, and contributions of the concept and artefact-under-development. After highlighting the features of the new approach compared to its traditional counterparts, the problem space for the system development is portrayed together with its design task complexities, followed by specifying the major PKMS research outputs. Having depicted the iterative PKMS design cycle, the problem, the rigor applied, and the contributions are presented in light of their relevance, and the evaluation methods employed, in progress, or projected are described.

As a result, this design science contribution pays recognition to a critical wicked problem and provides a conceptual solution with an innovative artefact (prototype-system-in-progress) that addresses it. To enhance the readability and value for managerial and technical audiences, all considerations and findings have been (for the first time) described and visualized in the context of Popper's Three Worlds and Digital Ecosystems. Visualizing all aspects of the PKMS concept – as evidenced in this article and all prior publications – plays a crucial role for successfully communicating the predicaments, complexities, solutions, and opportunities to a diverse portfolio of audiences.

"As academic scholars in applied fields our central mission is to develop theories that both contribute knowledge to the academic discipline (i.e., our internal stakeholders) and apply that knowledge to practice (i.e., our external stakeholders)" (attributed to Simon in O'Raghallaigh et al., 2011a, p. 117). The aim of this article has been just that by attempting to follow another of Simon's observations (1969, p. 132): Solving a problem simply means representing it so as to make the solution transparent.

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# Biography

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